Oct. 8.—Comet brighter. At beginning of observations comet in a straight line with two 9-mag. stars. Change in R.A. during evening very apparent. Observed with a star not in catalogue.

Oct. 11.—Evening very hazy; comet very faint.

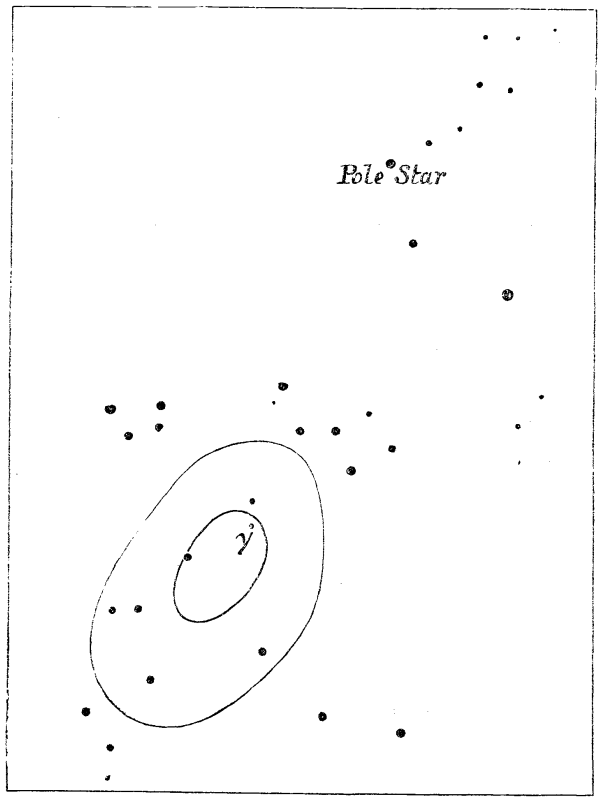
Oct. 12.—Comet faint.

On Evidence with respect to the Form of the Area in the Heavens from which the Meteors of November 27, 1885, appeared to Radiate. By A. C. Ranyard.

There were a great many observers of this rich shower, and most of them seem to agree that the meteors did not radiate from a point, but that there was a radiant area of some considerable extent. I did not observe the shower till well after its maximum at nearly nine o'clock; but from the forty or fifty meteors whose paths I observed, and was able to trace back upon the heavens (making a mental estimate of the distance of the radiant, judged from the length of the path and velocity), I thought that the area from which they radiated was elliptical, with its major axis nearly north and south, some 12° or 15° long, and a minor axis of 6° or 8°. I mentioned the elliptic shape of the area I had observed to Col. Tupman, and he told me that in the chart of paths he had laid down the radiant area was distinctly elliptical. But as I did not see any reason for such an elliptic form of the area, I regarded the coincidence as merely accidental, and thought that our results were probably not founded on a sufficient number of observed tracks. When Col. Tupman described his observations at the evening meeting of the Society, he stated that the longer axis of the elliptic area observed by him lay north and south. This struck me as an additional coincidence, for I felt sure that I had not mentioned to him the direction of the axes of the elliptic area observed by me; but I did not think seriously of the matter till a few weeks after, when I saw a letter from Prof. Young in *Nature* of December 17, in which, after describing his observations, he says that "the radiant was not a point but rather a region about 4° long north and south, and 2° wide." I then wrote to ask Prof. Young further about his observation, and he replied that the radiant region was "an oval area," perhaps a little larger than he had at first estimated.

Recently during a visit to the observatory at Nice, M. Perrotin showed me a map on which he and his assistants had laid down the courses of sixty or seventy meteors they had observed on the night of November 27. I at once saw that the paths did not radiate from a point, and without telling M. Perrotin of the other observations, I asked him to draw a contour line round the area of radiation. Both he and M. Thollon, who was present, drew elliptic curves with the longer axis north and south, or rather inclined 10° or 15° to the west of the north point.

The accompanying woodcut is made from the contour lines laid down by M. Perrotin and M. Thollon on a tracing from their map.



There therefore appears to be some very definite evidence that the paths of these meteors *did* radiate from an elongated area with its axis north and south. I have been thinking over the possible physical causes of such an elliptic area of radiation. If the paths of the meteors were all parallel they would appear to meet in a point. And if, on entering the earth's atmosphere, they were deflected from their original direction, and there was no greater tendency to deflection in one direction than in another, they would, on becoming luminous, move in paths which would be symmetrically arranged with respect to the original direction of motion, and an observer would refer them to a circular area of radiation with its centre corresponding to the original direction of motion outside the earth's atmosphere. If there were a greater tendency to scattering or "skidding" from the original direction of motion on entering the atmosphere in one direction rather than in the direction at right angles, the area of radiation would be elongated in the heavens in a direction corresponding with the direction of greatest "skidding." The elliptic area of radiation of the Biela meteors shows that their paths, at all events after they become luminous within the earth's atmosphere,

are not parallel, and that there is a greater tendency to deviate from the mean direction to the north and south than to the east and west.

It has been suggested by those who, like Sir Stawell Ball and Mr. Proctor, are inclined to believe that meteors were originally projected from the earth, that if they were ejected in slightly different directions they would not return moving in parallel paths; but if their paths outside the earth's atmosphere were not parallel, their orbits and their periods would be so very different that they would not come up to the earth again in a single swarm. We may therefore, I think, assume that the paths of the different components of a meteoric swarm are parallel in space before they encounter the earth's atmosphere, and that they are deflected by reason of their irregular shapes after they enter the earth's atmosphere, and usually before they become luminous, though there is abundant evidence that such deflection or "skidding" from their original course sometimes takes place after they become luminous. Professor Newton, Col. Tupman, and Mr. B. J. Hopkins have recorded meteors with curved paths. I have, on two occasions, seen meteors with curved paths, and there is a meteor with a very decidedly curved path in the chart of meteor tracks observed at Greenwich on the night of November 27, 1885, which is given at p. 62 of the December number of the *Monthly Notices* for 1885.

In order to account for the elliptic area, on the assumption that the deflection from the original path takes place within the earth's atmosphere, it is necessary to find some cause which would account for the deflection being greater in one plane than in the direction at right angles to it. This would be the case if there were some arrangement of the particles in space which caused them to set themselves with their longer axes north and south. I would suggest that if the particles are magnetic they would, on coming up to the earth, tend to arrange themselves with their longer axes parallel to the earth's magnetic axis. And in connection with this it is worth noticing that the axis of the contours drawn by M. Perrotin and M. Thollon do not point to the North Pole, but some 12° or 14° to the west of north, which about corresponds to the deviation of the magnetic meridian at Nice.

Neither Mr. Nash at Greenwich, who seems to have laid down with great care the tracks he gives in his chart, "principally from observations made between 8^h and 9^h 30^m," nor Mr. Denning, whose attention was attracted by the large area of radiation, seem to have noticed its elliptic shape. But with such slow-moving meteors as those of the Biela swarm, the elliptic shape of the area above referred to would probably be missed by observers who combined tracks laid down with an interval of three or four hours. For, owing to the axial rotation of the earth, the centre of radiation would appear to shift rapidly in the heavens in a direction nearly at right angles to the longer axis of the observed

ellipse. Thus, by combining observations separated by a sufficient interval of time, a circular area of radiation might be deduced, though the true area of radiation for any instant was an ellipse of considerable ellipticity.

Mr. Denning appears to think that the radiant area of this shower was larger than that usually observed. He says:—"In many cases I found that very accurately observed paths deviated several degrees from the mean. The area of radiation must have been fully 7° in diameter to accommodate the discordances in the flights. The centre was at 24°+44°; but I saw several very short paths from a point south of γ *Andromedæ*." This would seem to indicate that the radiant area was elongated in a north-westerly direction. Mr. Denning adds:—"I noted many of the meteors with the utmost care, in order to assure myself of the diffuseness of radiation, and it was found impossible to get a sharply defined position. The contrary effect was indeed so obvious as to arrest the eye whenever simultaneous bursts of about six or seven meteors took place near the radiant. It was then seen that the collective flights were not symmetrical emanations from a central point. They rather appeared to be discharged in a loose, disjointed fashion, from a comparatively large space on the N.W. region of γ *Andromedæ*, and just perhaps enveloping the star within its limits."

If the great extent of the radiant area should turn out to be peculiar to this shower, it would be evidence that the meteoric particles of the Biela stream are more irregular in shape than those of other streams. For example, one can conceive that they might be elongated crystalline forms, or a sponge-like meshwork of crystals containing magnetic iron, which has been torn into more than usually irregular shapes; or the irregular forms may be due to exposure to heat, which has evaporated volatile substances from the interstices of crystals with a higher melting point.

The size and shape of the area of radiation is well worthy of careful examination during future showers, noting the corresponding star magnitude of the meteor, observed beside each track laid down. Since the mass of similar-shaped meteoric particles varies as the cube of their diameter, while their resisting surface varies as the square of the diameter, we may expect to find the smaller particles heated to incandescence on entering the atmosphere more rapidly, and in a higher region, than larger masses, and the forces tending to deflect them from their original course bearing a larger proportion to the momentum the smaller the particle. It is probable that only the larger particles which enter the atmosphere become visible as naked-eye meteors, the dust-like particles being lost as telescopic meteors, or with a sudden spark, which, owing to distance and atmospheric absorption, may not be visible even as a telescopic meteor.

Some idea as to the size of meteoric particles capable of giving the light of a sixth-magnitude star may be derived from the

consideration that a standard candle, seen at the distance of a mile, is only a little brighter than a first-magnitude star. Consequently, without taking atmospheric absorption into account, an incandescent body at a distance of 100 miles would only appear as a sixth-magnitude star if it shone with a light about equal to that of an electric lamp of 100 candles power. As only the larger meteors enter the earth's atmosphere to a depth of below 70 miles above the surface, it may be assumed that few of the meteors seen, except those which appear in the zenith, approach within 100 miles of the observer. One may, consequently, pretty safely assume that a meteor which is just visible to the naked eye is larger than the portion of the carbons which is rendered incandescent in an arc-light of 100 candles power. For a mass of carbon such as is used for electric lighting purposes gives off more light while being driven into vapour than other substances which have been experimented upon; and the carbon of the electric light is not exposed to the tremendous bombardment of cold air, which must tend greatly to accelerate the disintegration of the meteoric particles in their passage through the air, as well as to cool their surface by removing the incandescent matter as rapidly as it is formed. If the above reasoning is correct, a much greater amount of matter must enter the Earth's atmosphere during a meteoric shower than has hitherto been supposed. Such matter would in time find its way to the Earth's surface, and when we consider geological periods of time, would have a sensible effect on the growth of the Earth, and the shape of continents.

Note on an Erratic Meteor. By B. J. Hopkins.

In November 1885 I had the honour of reading before the Society a Paper, containing a series of observations of mine of a class of meteors which from the apparent form of their paths I termed "erratic." I pointed out in that Paper that the appearance of these bodies was comparatively rare, and in proof of that statement I may here remark that, in a correspondence on the subject which I had with Mr. Denning, he informed me that, though he had observed considerably over 1,300 meteors during the year 1885, only four of them described paths similar to those mentioned in my Paper above referred to.

On account of their being so rarely seen, I have thought that a few remarks upon one I had the good fortune to observe on December 4, 18 hrs., would not be without interest; particularly as the meteor presented not only the peculiarity of a wavy path, but also had that path broken in two. The meteor referred to was of a brilliant white colour, and equalled *Jupiter* in apparent magnitude; it made its appearance near *ν Ursa Majoris*, and disappeared between *ι Draconis* and *γ Ursa Minoris*.